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Materiel Test Procedure 6-2-540
Electronic Proving Ground

U. S. ARMY TEST AND EVALUATION COMMAND
COMMON ENGINEERING TEST PROCEDURE

VIBRATION TESTS

1. OBJECTIVE

The objective of this materiel test procedure is to describe the laboratory procedures required to determine the effects of simulated service vibration on the performance and physical characteristics of Communication, Surveillance and Avionic electronic equipment relative to requirements as expressed in applicable Qualitative Materiel Requirements (QMR), Small Development Requirements (SDR), or other appropriate documentation.

2. BACKGROUND

The vibration test is one of a series of engineering environmental tests performed to provide confidence that the test item is constructed to withstand expected dynamic vibrational stresses and that performance degradations or malfunctions would not occur in the service vibration environment.

Vibration is a mechanical oscillation or motion about a reference point of equilibrium. This motion has six possible degrees of freedom, three linea- and three angular. The corresponding linear or angular displacements can be represented as a function of time with reference to any three mutually perpendicular rectilinear axes.

In general, vibration is analyzed using the single degree-of freedom approximation, that is, that motion occurs along only one orthogonal coordinate. Hence, vibration is characterized by a mean or central value about which the oscillation occurs, an amplitude describing the peak intensity of the vibration, and a frequency which describes the rate of occurence of the excitation.

Service environments may contain different types of vibration excitations such as sinusoidal, periodic (superposition of multiple-integer-frequency components) or complex.

The resulting motion or motions may be that of the equipment unit (whole-body motion) or of the parts of the equipment structure (deformation) relative to each other. Vibration may be either forced or free. A free vibrating element continues to oscillate at its natural frequency until the excitation is removed, and damping causes the oscillation to die out. A forced vibrating system is driven by some excitation which may be either periodic or random. The response frequencies of a forced vibrating system will contain elements of the forcing frequency as well as response frequencies of the structural elements.

Any whole-body motion is possible depending upon the external forces that act upon the equipment as a unit. While a wide variety of deformations is possible in any equipment structure, those that involve large stresses or large

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amplitudes of motion are of particular interest because of t[illegible] damaging effects. These particular motions occur during the condition of resonance. Resonance of a system during forced vibration is the maximum response condition that exists at a natural (resonant) frequency. Any change from this excitation frequency (with amplitude maintained constant) results in a decrease of response or deformation. The level of the resonant response, or resonant rise, is a function of the damping characteristics of the system. Damping is the dissipation of energy in a dynamic system which is manifested by a diminishing of system response with time. The lower the damping quotient, the higher the resonant response of the system (or quality factor Q) and the sharper the peak. Highly damped systems exhibit a broad response near the resonant frequency.

Possible adverse effects of expected vibration extremes during handling, transportation, and service use on military electronic equipment include the following:

a. Functional failure
b. Degradation of performance
c. Loss of calibration
d. Break of supporting structure, soldered joints, or lead wires
e. Fracture of material
f. Temporary short of conductors
g. Chatter of contacts
h. False reading of pointer-type devices
i. Change in crystalline structure of elements
j. Displacement of movable parts, such as screws and pins
k. Vibration of laminations
l. Motion of rotary devices
m. Chip or flake of finishes

Engineering tests must be performed, as applicable, to determine the resistance of electronic equipment to the effects of simulated vibration environments representative of those peculiar to military operations.

3. REQUIRED EQUIPMENT

a. Vibration testing system (See Appendix A)
b. Vibration transportation simulator
c. Vibration measurement system (See Appendix B)
d. Test apparatus, as required for operational tests of the test item
e. Support equipment, as required to operate the test item

4. REFERENCES

A. MIL-STD-781B, Reliability Tests: Exponential Distribution.
B. MIL-STD-810B, Environmental Test Methods.
C. MIL-E-5272C, Environmental Testing, Aeronautical and Associated Equipment, General Specification For.
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U. S. Army Electronics Command, Fort Monmouth, New Jersey, 1968 (Signal Corps Technical Requirement SCL-7851A).

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F. Stallard, R. L., The Philosophy of Vibration Testing, APL/JHU CF-2516, The Johns Hopkins University Silver Spring, Maryland, June 1, 1956, (AD 657-111).

G. Vibration Testing System 690M-40 Operating and Maintenance Manual, Unholtz-Dickie Corporation, Hamden, Connecticut.

H. Instruction Manual for L. A. B. Type 1000-SC Vibration Transportation Simulator, L. A. B. Corporation, Skaneateles, New York.

I. Instruction Manual, SD101A-MK III Dynamic Analyzer (Part One), Spectral Dynamics Corporation of San Diego, California, April 1967.

J. Instruction Manual, SD112 Voltmeter/Log Converter, Spectral Dynamics Corporation of San Diego, San Diego, California, April 1968.

K. Model 580 X-XY' Recorder Instruction Manual, Honeywell, Inc., San Diego, California.

L. Technical Instruction Manual: Model 39A Electro-Optical Tracking System, PhysiTech, Inc., Willow Grove, Pa.

M. MTP 2-1-003, Vibration Testing (General Guidance).

N. MTP 3-1-002, Confidence Intervals and Sample Size.

O. MTP 6-2-507, Safety.

5. SCOPE

5.1 SUMMARY

The procedures outlined in this MTP provide general guidance for determining the adverse effects on Communication, Surveillance, and Avionic electronic equipment caused by exposure of such equipment to simulated service vibration.

The cummulative test results will permit an estimate to be made of the ability of the test item to operate effectively and withstand physical degradation in the environment of intended use.

The specific tests to be performed (depending upon the category of equipment) consist of a number of procedures each containing various test types. These tests and their intended objectives are as follows:

a. Resonance Search - The objective of this test type is to determine resonant modes of the equipment when vibration is applied along each of the three mutually perpendicular axes of the equipment.

b. Resonance Dwell - The objective of this test type is to determine the effects of prolonged vibration along each axis of the test item at the most severe resonant frequencies.

c. Sinusoidal Cycling - The objective of this test type is to determine the effects of cycling the frequency of applied vibration to the test item at a logarithmic or linear cycling rate (Figure A-8).

d. Random - The objective of this test type is to determine the effects of random vibration on the test item.

e. Bounce, Vehicular - The objective of this test type is to determine the effects of simulated transportation vibrations on the test item.

f. Bounce, Loose Cargo - The objective of this test type is to determine whether the test item, as prepared for field use, is capable of withstanding the vibrations normally induced during transportation as loose cargo.

In the event the test item is to undergo other environmental tests in addition to vibration tests, the test scheduling shall be governed by the provisions of Appendix C, "Test Sequence".

5.2 LIMITATIONS

The procedures given in this document are limited to vibration testing under room ambient conditions, utilizing the vibration testing system and the vibration transportation simulator described herein. Vibration tests at other than ambient temperatures, as required by equipment specifications or other equivalent documents, shall be accomplished with the aid of a piggyback chamber.

Vibration tests for shipboard and amphibious equipment, and for equipment normally transported by a ship as a common carrier, are excluded from this document.

It is left as a task for the test officer to classify the test item as to proper "grouping" in accordance with Appendix A, and indicate the applicability of the test procedures, as well as to review the capabilities of the vibration machines to determine their suitability with regard to test item size and weight, and applicable specifications and standards.

6. PROCEDURES

6.1 PREPARATION FOR TEST

a. Upon establishing the scheduled availability of the test item, ensure that coordinated action is taken by the test officer and environmental engineer, as required to accomplish facility scheduling and implementation of test requirements to include personnel, equipment, maintenance support facilities, spare parts, and instrumentation with special attention to timely provision of additional supplies or equipment not readily available at the test site.

b. Select a testing facility (vibration machine) using the following criteria:

1) The volume of the test facility must be such that the equipment under test can be either operating or not operating and, will not interfere with the g[illegible]ation and maintenance of test environmental conditions.
2) All app[illegible]ratus used in conducting these tests mu[illegible] [illegible] capable

of producing and maintaining the test conditions required.

NOTE: Capabilities and controls of the vibration testing system available at the Environmental Test Facility of the U. S. Army Electronic Proving Ground, Fort Huachuca, Arizona, are given in Appendix B for reference purposes.

c. Select test equipment ideally having an accuracy of at least ten orders of magnitude greater than that afforded by the item under test, that is in keeping with the state of the art, and with calibrations traceable to the National Bureau of Standards.

d. Record the following information:

1) Nomenclature, serial number(s), manufacturer's name, and function of the item(s) under test.
2) Nomenclature, serial number, accuracy tolerances, calibration requirements, and last date calibrated of the test equipment selected for the test.

e. Ensure that all test personnel are familiar with the required technical and operational characteristics of the item under test, such as stipulated in Qualitative Materiel Requirements (QMR), Small Development Requirements (SDR), and Technical Characteristics (TC).

f. Review all instructional material issued with the test item by the manufacturer, contractor, or government, as well as reports of previous similar tests conducted on the same types of equipment. These documents shall be kept readily available for reference.

g. Prepare record forms for systematic entry of data including the pretest equipment record, chronology of test, test results, and such observations and measurements that would be of value in analysis and final evaluation.

h. Prepare adequate safety precautions to provide safety for personnel and equipment, and ensure that all safety SOP's are observed throughout the test and that the item has successfully completed the examination prescribed in MTP 6-2-507, Safety.

i. Prepare a test item sample plan sufficient to ensure that enough samples of all measurements are taken to provide statistical confidence of final data in accordance with MTP 3-1-002. Provisions shall be made for modification during test progress as may be indicated by monitored test results.

j. Thoroughly inspect the item under test for obvious physical and electrical defects such as cracked or broken parts, loose connections, bare or broken wires, loose assemblies, bent relay and switch springs, corroded plugs and jacks, and bare or cracked insulation. All defects shall be noted and corrected before proceeding with the test. Record the condition of all components that may undergo degradation in the simulated environment.

k. Prepare the vibration testing system for testing by performing a functional checkout procedure to include adjustment or servicing as required, and performance of appropriate maintenance. (See Appendix B)

6.2 TEST CONDUCT

NOTE: 1. When it is known that the equipment will encounter

conditions more severe or less severe than the environmental levels stated herein, the tests may be modified by the equipment specification.
2. All tests listed beside the applicable procedure number in Table A-I shall be performed.
3. The vibration environment specified by the test curve shall be applied to each of the three mutually perpendicular axes of the test item.
4. The entire sequence of tests may be accomplished for any one axis before changing to the next axis.

6.2.1 Procedure I (Resonance Search, Resonance Dwell, or Sinusoidal Cycling)

NOTE: This procedure is applicable to equipment which will be installed in aircraft including helicopters, and in part to the equipment which will be mounted in ground vehicles when the vehicle or its mileage schedule is not known.

a. Install the test item on the vibration exciter table in a manner that will simulate service usage, making connections and attaching instrumentation as necessary. Attach the test item by its normal mounting means either directly to the table, or by means of a rigid fixture capable of transmitting the vibration conditions specified herein. Rigidly attach and locate the input monitoring transducer(s) on or near the attachment point or points of the test item.

NOTE: 1. Whenever possible, distribute the test load uniformly on the table in order to minimize effects of unbalanced loads.
2. Allow plugs, covers, and inspection plates not used in operation, but used in servicing, to remain in place.
3. When mechanical or electrical connections are not used, adequately cover the connections normally protected in service.
4. In the case of vibration isolated equipment with isolators removed, mount the test item directly to the vibration table with external vibration isolators removed but including any other required holding devices.

b. Determine if the item under test is to be operated during the test cycle. If so, provide suitable arrangements to start, operate, monitor, and stop the unit without materially affecting the environment or the validity of the test.

c. Verify correct power source, inter-connection cabling, and that the unit is aligned, if necessary, as specified in the pertinent operating instructions to ensure, insofar as possible, it represents an average equipment in normal operating condition and that no damage or malfunction was caused by faulty installation or handling.

d. Operate the test item under standard ambient conditions, unless otherwise specified, and record all data necessary to determine compliance with required performance.

NOTE: 1. These data shall provide the criteria for checking satisfactory performance of the test item during and at the conclusion of the test.
2. The requirement for operation following installation of the test item in the test facility is applicable only when operation is required during or immediately following exposure to the specified test.

e. Perform a resonance search to determine resonant modes of the equipment by varying the frequency of applied vibration slowly through the specified range at reduced input amplitudes. Conduct individual resonance searches with vibration applied along each of the three mutually perpendicular axes of the equipment. The determination of resonance in equipment may be accomplished by several methods of observation and indicated by the following:

1) Maximum response of an accelerometer mounted on a resonating structure.
2) Slow oscillation of the visual image of a structural element when a stroboscope light is adjusted 1 to 2 Hz "out of sync" with the vibration frequency.
3) Sounds which occur during resonance such as that produced when elements bang together from extreme displacement.
4) Optical measurement with the electro-optical tracking system.

f. Record data as indicated in Table III.

g. Unless the test item is tested in a storage configuration, or as otherwise specified, operate the test item during the vibration exposure and record all data necessary to determine compliance with required performance. If the duration of the performance test is greater than the duration of the vibration test, abbreviate the performance test accordingly.

h. Return the vibration test facility to standard ambient conditions, operate the test item, and compare the results with the data obtained in accordance with step d above, (Pre-test equipment performance record).

i. Visually inspect the test item and record a description of any damage or deterioration resulting from the test.

j. Perform resonance dwell by vibrating the test item along each axis at the most severe resonant frequencies according to the time schedule I of Table A-II and the applicable double amplitudes or accelerations of the specified curve from Figure A-1, A-2, or A-5. Unless otherwise specified, for test items weighing more than 50 pounds reduce the vibratory accelerations by ±1 g for each 10 pound increment of weight over 50 pounds. However, the vibratory acceleration shall in no case be less than 50 percent of the specified curve level. When Figure A-5 is specified and the equipment weighs more than 100 pounds, reduce the upper frequency limit of Figure A-5 according to the cut-off frequency vs. weight requirement of Figure A-7.

NOTE: 1. If more than four significant resonances have been found for any one axis, chose the four most severe resonances for the test.
2. If a change in the resonant frequency occurs during the

test, adjust the frequency to maintain the resonance condition.
3. Maintain the vibratory acceleration levels or double amplitudes at the test item mounting points.
4. When the input vibration is measured at more than one control point, ensure that the minimum input vibration is normally that of the specified curve.
5. For massive test items, fixtures, large force exciters or multiple vibration exciters, it is recommended that the input control level be an average of at least three or more inputs.
6. Unless otherwise specified, limit the transverse motion at the input monitoring point(s) to 100 percent of the input motion.
7. Crosstalk limitation of small equipment (20 pounds or less) can usually be achieved, however, such limitation for larger equipment may not be possible.

k. Record data as indicated in Table III.

l. Repeat steps g, h, and i, above.

m. Subject the test item to sinusoidal cycling by cycling the frequency of applied vibration at a logarithmic rate, in accordance with Figure A-8 and the time schedule of Table A-II between the frequency limits and at the vibratory acceleration levels of the specified curve from Figure A-1, A-2, or A-5. Unless otherwise specified, for test items weighing more than 50 pounds, reduce the vibratory accelerations by ± 1 g for each 10 pound increment of weight over 50 pounds. However, the vibratory acceleration shall in no case be less than 50 percent of the specified curve level. When Figure A-5 is specified and the equipment weighs more than 100 pounds, reduce the upper frequency limit of Figure A-5 according to the cut-off frequency versus weight requirement of Figure A-7. A linear cycling rate may be substituted for logarithmic cycling, when performed as follows:

1) Divide the total frequency range into logarithmic frequency bands of equal cycling time intervals by reference to Figure A-8.
2) Determine the linear cycling rate for each band by dividing each bandwidth in Hertz by the time in minutes for each band. For the 2 to 500 Hz and 5 to 2,000 Hz frequency ranges, use the frequency bands and linear cycling rates shown in Table I. For test frequency ranges of 100 Hz or less, no correction of the linear cycling rate is required.

NOTE: 1. Maintain the vibratory acceleration levels or double amplitudes at the test item mounting points.
2. When the input vibration is measured at more than one control point, ensure that the minimum input vibration is normally that of the actual or modified specified curve level.
3. For massive test items, fixtures, large force exciters

or multiple vibration exciters, it is recommended that the input control level be an average of at least three or more inputs.

4. Unless otherwise specified, limit the transverse motion at the input monitoring point(s) to 100 percent of the input motion.
5. Crosstalk limitation of small equipment (20 pounds or less) can usually be achieved, however, such limitation for larger equipment may not be possible.

Table I. Linear Cycling Rates

Total Frequency Range	Frequency Bands	Sweep Time in Minutes	Linear Cycling Rate Hz/min
2-500 Hz	2 to 5 5 to 22.5 22.5 to 100 100 to 500	1.5 2.5 2.5 2.5	2 7 31 160
5-2000 Hz	5 to 22.5 22.5 to 100 100 to 500 500 to 2000	2.5 2.5 2.5 2.5	7 31 160 600

n. Repeat steps g, h, and i, above.

o. Repeat steps b thru n above, for vibration isolated equipment with external vibration isolators removed, except with the test level at the lower g level specified and the time schedule II of Table A-II.

6.2.2 Procedure II

NOTE: This procedure is applicable to equipment which will be installed in air launched vehicles and mounted without vibration isolators.

a. Conduct a Pre-test equipment performance check of the item under test as outlined in steps a through d of paragraph 6.2.1.

b. Subject the test item to resonance search, resonance dwell, and sinusoidal cycling vibrations as outlined in steps e through n of paragraph 6.2.1, except with the test level in accordance with curve C, D, H, or J from Figure A-1 and time schedule V of Table A-II.

c. Repeat the sinusoidal cycling test as outlined in steps m and n of paragraph 6.2.1, except with the test level in accordance with curve P, Q, R, and S of Figure A-3 and time schedule II of Table A-II.

d. Apply random vibration to the test item according to one specified curve of AF through AK from Figure A-4 and time schedule II of Table A-II.

NOTE: 1. The instantaneous random vibration acceleration peaks (g)

may be limited to 3 times the rms (g) acceleration level.

2. If there are resonant modes of the moving mass (vibration exciter moving element, fixture and either the test item or substitute equivalent mass) within the frequency range of the test curve, equalize, or compensate for them.

3. Maintain the applied vibration spectrum within the tolerances of +40, -30 percent between the frequencies of 50 and 1000 Hz, and within +300, -50 percent between 1,000 and 2,000 Hz. For a power spectral density analysis of the test spectrum, these tolerances may be expressed as ± 1.5 db and ± 3 db, respectively. Tolerance levels in terms of db are defined as:

$$\text{db} = 10 \log \frac{(G_1)^2/\text{Hz}}{(G_o)^2/\text{Hz}} \quad \text{or}$$

$$\text{db} = 20 \log \frac{G_1}{G_o}$$

where G_1 = G rms (measured over the analyzer effective bandwidth), and the term G_o defines the specified level.

4. To assure the specified equalization tolerances, use a wave analyzer with the following characteristics:

Filter bandwidths = B = 25 Hz
Max. below 1000 Hz and 1/3 octave max. above 1000 Hz

Sweep rate = R = $B^2/32$ Hz/sec. max.

Integrator time constant = 1 second minimum

e. Record data as indicated in Table III.

f. Return the vibration test facility to standard ambient conditions, operate the test item, and compare the results with the data obtained in accordance with step a above, (Pre-test equipment performance record).

g. Visually inspect the test item and record a description of any damage or deterioration resulting from the test.

6.2.3 Procedure III

NOTE: This procedure is applicable to equipment which will be installed in air launched vehicles and mounted with vibration isolators.

a. Conduct a Pre-test equipment performance check of the test item as

outlined in steps a through d of paragraph 6.2.1.

b. With vibration isolators in place, subject the test item to resonance search, resonance dwell and sinusoidal cycling vibrations as outlined in steps e through n of paragraph 6.2.1, except with the test level in accordance with curve C, D, H, or J from Figure A-1 and time schedule V of Table A-II.

c. Remove the vibration isolators and repeat step b above, except with the test level in accordance with curve A, B, or K from Figure A-3 and time schedule II of Table A-II.

d. Replace the vibration isolators and repeat the sinusoidal cycling test as outlined in steps m and n of paragraph 6.2.1, except with the test level in accordance with curve P, Q, R, or S from Figure A-3 and time schedule II of Table A-II.

e. With the isolators in place, subject the test item to random vibration in accordance with step d of paragraph 6.2.2.

f. Record data as indicated in Table III.

g. Return the vibration test facility to standard ambient conditions, operate the test item, and compare the results with the data obtained in accordance with step a above (Pre-test equipment performance record).

h. Visually inspect the test item and record a description of any damage or deterioration resulting from the test.

6.2.4 Procedure IV

NOTE: This procedure is applicable to equipment normally using vibration isolators which will be installed in air launched vehicles, but tested without vibration isolators.

a. Conduct a Pre-test equipment performance check of the item under test as outlined in steps a through d of paragraph 6.2.1, except without vibration isolators on the test item.

b. Subject the test item to resonance search, resonance dwell, and sinusoidal cycling vibrations as outlined in steps e through n of paragraph 6.2.1, except with the test level in accordance with curve A, B, or K from Figure A-1 and time schedule V of Table A-II.

c. Repeat the sinusoidal cycling test as outlined in steps m and n of paragraph 6.2.1, except with the test level in accordance with curve N from Figure A-3 and time schedule II of Table A-II.

d. Subject the item under test to random vibration in accordance with step d of paragraph 6.2.2, except according to curve AE from Figure A-4 and time schedule II of Table A-II.

e. Record data as indicated in Table III.

f. Return the vibration test facility to standard ambient conditions, operate the test item, and compare the results with the data obtained in accordance with step a above, (Pre-test equipment performance record).

g. Visually inspect the test item and record a description of any damage or deterioration resulting from the test.

6.2.5 Procedure V

NOTE: This procedure is applicable to equipment which will be

installed in ground launched vehicles and mounted without vibration isolators.

a. Conduct a Pre-test equipment performance check of the item under test as outlined in steps a through d of paragraph 6.2.1.

b. With vibration isolators in place, subject the test item to resonance search, resonance dwell, and sinusoidal cycling vibrations as outlined in steps e through n of paragraph 6.2.1, except with the test level in accordance with one curve of P through U from Figure A-3 and time schedule II of Table A-II.

c. Subject the item under test to random vibration in accordance with step d of paragraph 6.2.2, except according to one specified curve of AE through AP from Figure A-4 and time schedule II of Table A-II.

d. Record data as indicated in Table III.

e. Return the vibration test facility to standard ambient conditions, operate the test item, and compare the results with the data obtained in accordance with step a above, (Pre-test equipment performance record).

f. Visually inspect the test item and record a description of any damage or deterioration resulting from the test.

6.2.6 Procedure VI

NOTE: This procedure is applicable to equipment which will be installed in ground launched vehicles and mounted with vibration isolators.

a. Conduct a Pre-test equipment performance check of the test item as outlined in steps a through d of paragraph 6.2.1.

b. With the vibration isolators in place, subject the item under test to the sinusoidal cycling test as outlined in steps m and n of paragraph 6.2.1, except with the test level in accordance with one curve of P through U from Figure A-3 and time schedule II of Table A-II.

c. Remove the vibration isolators, mount the test item rigidly to the vibration table, and, again subject the test item to sinusoidal cycling with the test level in accordance with curve N from Figure A-3 and time schedule II of Table A-II.

d. Replace the vibration isolators and subject the item under test to random vibration in accordance with step d of paragraph 6.2.2, except according to one specified curve of AE through AP from Figure A-4 and time schedule II of Table A-II.

e. Record data as indicated in Table III.

f. Return the vibration test facility to standard ambient conditions, operate the test item, and compare the results with the data obtained in accordance with step a above, (Pre-test equipment performance record).

g. Visually inspect the test item and record a description of any damage or deterioration resulting from the test.

6.2.7 Procedure VII

NOTE: This procedure is applicable to equipment normally using

vibration isolators which will be installed in ground launched vehicles, but tested without vibration isolators.

a. Conduct a Pre-test equipment performance check of the item under test as outlined in steps a through d of paragraph 6.2.1, except without vibration isolators on the test item.

b. Subject the item under test to the sinusoidal cycling test as outlined in steps m and n of paragraph 6.2.1, except with the test level in accordance with curve N from Figure A-3 and time schedule II of Table A-II.

c. Subject the item under test to random vibration in accordance with step d of paragraph 6.2.2, except according to one specified curve AE from Figure A-4 and time schedule II of Table A-II.

d. Record data as indicated in Ta' III.

e. Return the vibration test faci...y to standard ambient conditions, operate the test item, and compare the results with the data obtained in accordance with step a above, (Pre-test equipment performance record).

f. Visually inspect the test item and record a description of any damage or deterioration resulting from the test.

6.2.8 Procedure VIII

NOTE: This procedure is applicable to equipment which will be installed in ground vehicles and is used for more realistic testing when the vehicle mileage is known.

a. Conduct a Pre-test equipment performance check of the item under test as outlined in steps a through d of paragraph 6.2.1.

b. Subject the test item to resonance search, resonance dwell, and sinusoidal cycling vibrations as outlined in steps e through n of paragraph 6.2.1, except using curve V, W, or Y from Figure A-5 and time schedule III of Table A-II. For equipment weighing more than 100 pounds, reduce the upper frequency limit of Figure A-5 according to the cut-off frequency versus weight requirement of Figure A-7.

NOTE: Calculate cycling time per axis for time schedule III as follows:

Cycling time per axis = 20 min/1000 miles x Total mileage
where total mileage is obtained from Table II, Mileage schedule.

c. Record data as indicated in Table III.

d. Return the vibration test facility to standard ambient conditions, operate the test item, and compare the results with the data obtained in accordance with step a above, (Pre-test equipment performance record).

e. Visually inspect the test item and record a description of any damage or deterioration resulting from the test.

6.2.9 Procedure IX

NOTE: This procedure is applicable to equipment which will be installed in ground vehicles and is used in addition to

Table II. Mileage Schedule

Group	Classification	Total Mileage
Trailers, semi-trailers and dollies:		
A	Trailers, semitrailers and dollies--------	6,000
B	Trailer bodies and equipment-------------	3,000
C	Electronic and missile systems trailers and semitrailers-----------------------	4,000
Wheeled vehicles:		
D	Tactical trucks--------------------------	25,000
E	Truck bodies, equipment------------------	11,400
F	Light weight, low mileage trucks	
	1 - Sprung type--------------------	4,000
	2 - Unsprung type------------------	5,000
G	High flotation vehicle-------------------	4,000
H	Amphibious-------------------------------	8,400
I	Fire trucks------------------------------	5,000
J	Commercial trucks, buses, passenger cars--	35,000
Tracked vehicles:		
K	Tanks and self-propelled (SP) weapons-----	5,000
L	Armored personnel carriers (APC), cargo carriers, missile support vehicles, wreckers, recovery vehicles and cargo tractors with towed load---------------	6,000
M	Engineer combat vehicle (ECF) and engineer assult vehicle, etc.-------------------	5,000
N	Engineer crawler tractors - military type-	6,000
O	Amphibious vehicles (LVT type)------------	5,000
P	Turret-mounted accessories such as integrally mounted flamethrowers and search lights---------------------------------	700
Q	Bulldozers------------------------------	200
R	Fording kits----------------------------	50

Procedure I and VII when the equipment might not always be installed but may be carried in a vehicle.

a. Conduct a Pre-test equipment performance check of the item under test as outlined in steps a through d of paragraph 6.2.1.

b. Subject the item under test to resonance search vibrations by vibrating the test item successively in three mutually perpendicular directions over a frequency range of 10 to 55 cycles per second, with a total excursion of the applied vibration of not less than 0.030 inch, and record all resonant frequencies where the equipment amplitude exceeds twice the amplitude of the applied vibration. In each of the three directions change the frequency in steps of 1 cycle per second and maintain the frequency for at least 10 seconds.

NOTE: 1. The test item shall be secured to the vibration table, using a mounting method such that the vibration within the test item can be observed and measured. Shock mounts (if any) of the test item shall be blocked.

2. Measure vibration amplitudes by optical or any other means, provided that the measurement does not affect the vibration of the test item.

c. Record data as indicated in Table III.

d. Return the vibration test facility to standard ambient conditions, operate the test item, and compare the results with the data obtained in accordance with step a above, (Pre-test equipment performance record).

e. Cover the test bed of the transportation simulator with a panel of 1/2-inch plywood, with the grain parallel to the drive chain. Secure the plywood with sixpenny nails, with top of heads flush with, or slightly below, the surface. Space nails at 6-inch intervals around all four edges.

NOTE: If the distance between either pair of fences is greater than 24 inches, nail the plywood also at 3-inch intervals in a 6-inch square at the center of the test area.

f. Using suitable wooden fences, constrain the vehicular, or simulated, adapter plate to a horizontal motion of not more than 2 inches in any lateral direction. Place fences at a distance from the test item more than sufficient to ensure that the test item will not rebound from fence to fence.

CAUTION: To safeguard personnel, use additional barriers as necessary.

g. Secure the test item to the vehicular, or simulated, adapter plate in a manner that will simulate service usage, making connections and attaching instrumentation as necessary, and place on the transportation simulator within the constraints outlined in step f.

NOTE: 1. If the test item weighs over 200 pounds, use a simulated adapter plate.

2. Allow plugs, covers, and inspection plates not used in

operation, but used in servicing, to remain in place.
3. When mechanical or electrical connections are not used, adequately cover the connections normally protected in service.

h. Operate the test item to determine that no malfunction or damage was caused due to faulty installation or handling.

i. Attach an accelerometer as close as possible to the point of test item attachment to record the shock transmitted to the test item.

j. Subject the item under test to vehicular bounce vibrations by adjusting the transportation simulator, shafts in phase and table operating in a vertical linear motion, to a speed in no case greater than 285 rpm, such that the average value of the random acceleration peaks is 7.5 ± 2.5 g's, and maintaining the speed for 3/4 hour.

NOTE: 1. Measure this input with an accurate measuring or recording system incorporating a 100 cycles per second low pass filter.
2. Due to the random nature of the input, pulses greater than 10 g's can be expected to occur, however, if they are infrequent, they need not be used in calculating the average.

k. At the end of each 3/4-hour period (step j, above), rotate the adapter plate and test item 90 degrees, each time in the same direction, and continue this procedure to conduct the test for a total of 3 hours.

l. Record data as indicated in Table III.

m. Repeat step d, above.

n. Visually inspect the test item and record a description of any damage or deterioration resulting from the test.

6.2.10 Procedure X

NOTE: This procedure is applicable to equipment which will be shipped by common carrier (land or air) as tied down cargo and generally to ground equipment (excluding ground vehicles) which will be tied down.

a. Conduct a Pre-test equipment performance check of the item under test as outlined in steps a through d of paragraph 6.2.1.

b. Subject the test item to resonance search, resonance dwell, and sinusoidal cycling vibrations as outlined in steps e through n of paragraph 6.2.1, except with the test level in accordance with curve AB or curves AA and AQ from Figure A-6 and time schedule IV of Table A-II. For equipment weighing more than 100 pounds, reduce the upper frequency limit of Figure A-6 according to the cut-off frequency versus weight requirement of Figure A-7.

c. Record data as indicated in Table III.

d. Return the vibration test facility to standard ambient conditions, operate the test item, and compare the results with the data obtained in accordance with step a above, (Pre-test equipment performance record).

e. Visually inspect the test item and record a description of any

damage or deterioration resulting from the test.

6.2.11 Procedure XI

NOTE: This procedure is applicable to equipment which will be shipped by common carrier (land or air) as loose cargo, and to ground equipment (excluding ground vehicles) where it is used in addition to Procedure X when the equipment might be subject to rough handling.

a. Conduct a Pre-test equipment performance check of the item under test as outlined in steps a through d of paragraph 6.2.1.

b. Subject the test item to resonance search vibrations as outlined in steps b, c, and d of paragraph 6.2.9.

c. With the item under test secured to the transportation simulator, as outlined in steps e, f, and g of paragraph 6.2.9, subject the test item to vehicular bounce vibrations by operating the transportation simulator for a total of 3 hours at a speed of 284 rpm ± 2 rpm either in the synchronous mode (any point on the bed of the tester will move in a circular path in a vertical plane perpendicular to the axes of the shafts), or instead, in the vertical linear mode (straight up and down in the vertical plane) when one of the following conditions occurs:

1) Bouncing of the test item is very severe and presents a hazard to personnel.
2) Forward and rear oscillations cannot be reduced.

CAUTION: When operated in the vertical linear mode, place wooden fences on all four sides of the test item to constrain its motion to not more than 2 inches in either direction.

d. At the end of each 1/2-hour period, turn the test item to rest on a different face, so that at the end of the 3-hour period the test item will have rested on each of its six faces (top, bottom, sides and ends).

e. Record data as indicated in Table III.

f. Return the test facility to standard ambient conditions, operate the test item, and compare the results with the data obtained in accordance with step a above, (Pre-test equipment performance record).

g. Visually inspect the test item and record a description of any damage or deterioration resulting from the test.

6.3 TEST DATA

6.3.1 Preparation For Test

Data to be recorded prior to testing shall include but not be limited to:

a. Nomenclature, serial number(s), manufacturer's name, and function of the item(s) under test.

b. Nomenclature, serial number, accuracy tolerance, calibration requirements, and last date calibrated of the test equipment selected for the tests.

c. Damages to the test item incurred during transit and/or manufacturing.

d. Condition of all components expected to undergo degradation as a result of exposure to the mechanical shock environment.

6.3.2 Test Conduct

Data to be recorded in addition to specific instructions listed below for each sub-test shall include:

a. A block diagram of the test setup employed in each specified test. The block diagram shall identify by model and serial number, all test equipment and interconnections (cable lengths, connectors, attenuators, etc.) and indicate control and dial settings where necessary.

b. Photographs or motion pictures (black and white or color), sketches, charts, graphs, or other pictorial or graphic presentation which will support test results or conclusions.

c. An engineering logbook containing, in chronological order, pertinent remarks and observations which would aid in a subsequent analysis of the test data. This information may consist of temperatures, humidity, pressures, and other appropriate environmental data, or other description of equipment or components, and functions and deficiencies, as well as theoretical estimations, mathematical calculations, test conditions, intermittent or catastrophic failures, test parameters, etc., that were obtained during the test.

d. Test item sample size (number of measurement repetitions).

e. Instrumentation or measurement system mean error stated accuracy.

f. Room or laboratory (in which the vibration table is located) environmental ambient conditions, including:

1) Temperature (°F)
2) Pressure (in. of Hg)
3) Relative Humidity (%)
4) Altitude (ft. above mean sea level)
5) Time and date of readings

g. Operational performance data for test item, as required, including input voltages.

h. Description and/or photograph of any damage or deterioration to the test item.

6.3.2.1 Procedure I

Procedure I test data shall be recorded as indicated in Table III.

6.3.2.2 Procedure II

Procedure II test data shall be recorded as indicated in Table III.

Table III Vibration Test Data (Paragraph 6.3.2 Exposure Procedures)

TEST TYPE AND DATA	PROCEDURE AND PARAGRAPH					
	I	II	III	IV	V	VI
	6.3.2.1	6.3.2.2	6.3.2.3	6.3.2.4	6.3.2.5	6.3.2.6
RESONANCE SEARCH:						
Frequency (Hz) of applied vibration for each resonant mode	X	X	X	X		
Excursion (in) of applied vib.						
Maintained-freq. period (sec.)						
Freq. (Hz) (t. i. amplitude exceeds twice ap. vib. amp.)						
T. I. amplitude (in) at reson.						
RESONANCE DWELL:						
Frequency (Hz)	X	X	X	X		
Acceleration level (± g peak), or double amplitude (in.)	X	X	X	X		
Dwell time (min.) at resonance	X	X	X	X		
Functional effects on t. i.	X	X	X	X		
SINUSOIDAL CYCLING:						
Frequency limits (Hz)	X	X	X	X	X	X
Acceleration level (± g peak) for the frequency range	X	X	X	X	X	X
Sweep time (min.)	X	X	X	X	X	X
Cycling time (hr.)	X	X	X	X	X	X
Cycling rate (log. or linear)	X	X	X	X	X	X
Test item performance data	X	X	X	X	X	X
RANDOM:						
Acceleration power spectral density (g^2/Hz)		X	X	X	X	X
Overall minimum acceleration (g rms)		X	X	X	X	X
Random time (min.)		X	X	X	X	X
Test item performance data		X	X	X	X	X
BOUNCE, VEHICULAR:						
Speed (rpm) of transportation simulator shafts-vertical linear mode						
Average value of random acceleration peaks (g)						
BOUNCE, LOOSE CARGO:						
Speed (rpm) of transportation simulator shafts						
Operational mode (synchronous or vertical linear)						

Table III continued on following page.

Table III Vibration Test Data (Paragraph 6.3.2. Exposure Procedures) (Cont'd)

TEST TYPE AND DATA	PROCEDURE AND PARAGRAPH				
	VII	VIII	IX	X	XI
	6.3.2.7	6.3.2.8	6.3.2.9	6.3.2.10	6.3.2.11
RESONANCE SEARCH:					
Frequency (Hz) of applied vibration for each resonant mode		X		X	
Excursion (in) of applied vib.			X		X
Maintained-freq. period (sec.)			X		X
Freq. (Hz) (t. i. amplitude exceeds twice ap. vib. amp.)			X		X
T. I. amplitude (in) at reson.			X		X
RESONANCE DWELL:					
Frequency (Hz)		X		X	
Acceleration level (± g peak) or double amplitude (in.)		X		X	
Dwell time (min.) at resonance		X		X	
Functional effects on t. i.		X		X	
SINUSOIDAL CYCLING:					
Frequency limits (Hz)	X	X		X	
Acceleration level (± g peak) for the frequency range	X	X		X	
Sweep time (min.)	X	X		X	
Cycling time (hr.)	X	X		X	
Cycling rate (log. or linear)	X	X		X	
Test item performance data	X	X		X	
RANDOM:					
Acceleration power spectral density (g^2/Hz)	X				
Overall minimum acceleration (g rms)	X				
Random time (min.)	X				
Test item performance data	X				
BOUNCE, VEHICULAR:					
Speed (rpm) of transportation simulator shafts-vertical linear mode			X		
Average value of random acceleration peaks (g)			X		
BOUNCE, LOOSE CARGO:					
Speed (rpm) of transportation simulator shafts					X
Operational mode (synchronous or vertical linear)					X

NOTE: Unless otherwise indicated, test data pertains to applied vibration characteristics along each of the test item's three mutually perpendicular axes.

6.3.2.3 Procedure III

Procedure III test data shall be recorded as indicated in Table III.

6.3.2.4 Procedure IV

Procedure IV test data shall be recorded as indicated in Table III.

6.3.2.5 Procedure V

Procedure V test data shall be recorded as indicated in Table III.

6.3.2.6 Procedure VI

Procedure VI test data shall be recorded as indicated in Table III.

6.3.2.7 Procedure VII

Procedure VII test data shall be recorded as indicated in Table III.

6.3.2.8 Procedure VIII

Procedure VIII test data shall be recorded as indicated in Table III.

6.3.2.9 Procedure IX

Procedure IX test data shall be recorded as indicated in Table III.

6.3.2.10 Procedure X

Procedure X test data shall be recorded as indicated in Table III.

6.3.2.11 Procedure XI

Procedure XI test data shall be recorded as indicated in Table III.

6.4 DATA REDUCTION AND PRESENTATION

a. Reduce, correlate, and present the data outlined in Table III and paragraph 6.3 in a manner that will describe the progressive changes in test item characteristics which results from the vibration exposure.

1) Present performance data comparison statements indicating the difference in selected performance characteristics.
2) Present physical characteristics data in the chronological series of descriptions or photographs, delineating the points, degree, and type of damage or deterioration.

b. Draw and present a conclusion as to the acceptability of the test item based on known criteria. If the test item is unacceptable, list specific reasons along with recommended corrective measures.

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APPENDIX A

VIBRATION TESTING

1. GENERAL

The procedures herein, designated by Roman numerals, provide for exposing the test item to machine-simulated vibrational environments or test types to various test levels within specific time schedules, based upon the appropriate equipment grouping category, as shown in Tables A-I and A-II.

Test types applicable to various procedures are indicated by an "X" in the appropriate column of Table A-I to the right of the test procedure number. The applicability of alternate test procedures contained in table A-I is based on the category of equipment and on other conditions as indicated in Table A-II.

2. EQUIPMENT CLASSIFICATION

For purposes of this document, equipment is categorized according to the vehicle in which it will be installed or according to other conditions as follows:

CATEGORY

a. Aircraft (including helicopters)
b. Aircraft (excluding helicopters)
c. Helicopters
d. Air launched vehicle
e. Ground launched vehicle
f. Ground vehicles
g. Shipment by common carrier, land or air
h. Ground equipment (excluding category (f))

3. TEST CURVES

Test curves applicable to various procedures are identified by capital letters to the right of the test procedure number and are given in Figure A-1 through A-6 (modified by data of Figure A-7 as required). In some instances several curves are indicated for one procedure. In this case it is necessary to select and specify a curve after making a detailed analysis of the expected vibration environment within the particular vehicle involved. Factors for consideration include the following:

a. Equipment location with respect to predominant vibration sources, such as high intensity noise of jet and rocket exhausts, aerodynamic excitation including atmospheric wind and turbulence, and unbalance of rotating parts.
b. Attenuation or amplification and filtering by structural members.

NOTE: Suggested vibration test curves for launched vehicles according to thrust to weight ratios and equipment locations are provided in Table A-IV.

Table A-I. Vibration Test Selection Chart

Equipment Catetory	Test Procedures: Procedure	Curve (Note 1)	Figure	Exposure paragraph	Test Type: Resonance search	Resonance dwell	Sinusoidal cycling	Random	Bounce, vehicular	Bounce, loose cargo	Time Schedule Table II
(a) Aircraft including Helicopters	I	Z	1	6.2.1	X	X	X				I
		B	1	6.2.1	X	X	X				II
(b) Aircraft except Helicopters	I	C, D, E, F, G, H, J, or L	1 or 2	6.2.1	X	X	X				I
		A, B, or K	1 or 2	6.2.1	X	X	X				II
(c) Helicopters	I	M	1	6.2.1	X	X	X				I
		B	1	6.2.1	X	X	X				II
(d) Air launched vehicles	II	C, D, H or J	1 or 2	Captive phase 6.2.2	X	X	X				V
		P, Q, R or S	3	Flight phase 6.2.2			X				II
		one of AF thru AK	4	6.2.2				X			II
	III	C, D, H or J	1 or 2	Captive phase 6.2.3	X	X	X				V
		A, B, or K	1 or 2	(Note 2) 6.2.3	X	X	X				II
		P, Q, R or S	3	Flight phase 6.2.3			X				II
		one of AF thru AK	4	6.2.3				X			II
	IV	A, B, or K	1 or 2	Captive phase 6.2.4	X	X	X				V
		N	3	Flight phase 6.2.4			X				II
		AE	4	6.2.4				X			II

Table A-I. continued on the following page.

Table A-I. (continued)

(e) Ground launched vehicles	V	one of P thru U	3	6.2.5			X				II
		one of AE thru AP	4	6.2.5				X			II
	VI	one of P thru U	3	6.2.6			X				II
		N	3	Note 2 6.2.6			X				II
		one of AE thru AP	4	Note 2 6.2.6				X			II
	VII	N	3	6.2.7			X				II
		AE	4	6.2.7				X			II
(f) Ground vehicles	I	V, W, or Y	5	6.2.1 (Note 3)	X	X	X				I
	VIII	V, W, or Y	5	6.2.8 (Note 3)	X	X	X				III
	IX			6.2.9	X				X		
(g) Shipment com. car.	X	AB or (AA&AQ)	6	6.2.10 (Note 3)	X	X	X				IV
	XI			6.2.11	X					X	
(h) Ground equipment excluding category (f)	X	AB or (AA&AQ)	6	6.2.10 (Note 3)	X	X	X				IV
	XI			6.2.11	X					X	

Note 1: Unless otherwise specified in the equipment specification for resonance and sinusoidal vibration cycling tests of items weighing more than 50 pounds, the vibratory accelerations shall be reduced by $\pm$ 1 g for each 10 pound increment of weight over 50 pounds. However, the vibratory acceleration shall in no case be less than 50 percent of the specified curve level.

Note 2: Tes items of equipment normally provided with vibration isolators shall first be tested with the isolators i place. The isolators shall then be removed, the test item rigidly mounted, and subjected to the low level indicated.

Note 3: When a transit case or crate is provided for the item, the case or crate shall be included in the test setup. For equipment weighing more than 100 pounds, the upper frequency limit of Figure A-5 or A-6 shall be reduced according to the cut-off frequency vs. weight requirement of Figure A-7.

Table A-II. Time Table

Time Schedule	Resonance Dwell		Cycling Time per axis	Random time per axis	Sweep Time	
	Number of Resonances	Time at resonance per axis			5-500-5 Hz	5-2000-5 Hz
I	0 1 2 3 4 Dwell 30 min. at each resonance	- 1/2 hr. 1 hr. 1 1/2 hr. 2 hr.	3 hr. 2 1/2 hr. 2 hr. 1 1/2 hr. 1 hr.		15 min. Note 1	20 min.
II	0 1 2 3 4 Dwell 10 min. at each resonance	- 10 min. 20 min. 30 min. 40 min.	30 min.	30 min.	15 min.	20 min.
III	0 1 2 3 4	- Dwell 1/6 of cycling time at each resonance (30 min. max.)	20 min/1000 miles as determined from vehicle mileage chart or equipment specification see Table II		15 min. Note 1	

Table A-II continued on following page.

Table A-II(continued)

Time Schedule	Resonance Dwell		Cycling Time Per Axis	Random Time Per Axis	Sweep Time	
	Number of Resonances	Time at resonance per axis			5-500-5 Hz	5-2000-5 Hz
IV	0 1 2 3 4 Dwell 30 min. at each resonance (see Note 2)	- 1/2 hr. 1 hr. 1 1/2 hr. 2 hr.	45 min. Note 1		15 min. Note 1	
V	0 1 2 3 4 Dwell 30 min. at each resonance	- 1/2 hr. 1 hr. 1 1/2 hr. 2 hr.	2 hr. 1 1/2 hr. 1 hr. 1/2 hr. 0		15 min.	20 min.

Note 1: Sweep time can be as long as 18 minutes if test frequencies go lower than 5 Hz (See Figures A-5 and A-6).

Note 2: When testing to curve AQ of Figure A-6, the 30 minute dwell time shall be broken into six 5-minute vibrations with five 2-minute shut down intervals.

Table A-III. Applicable Procedure for Equipment Category

EQUIPMENT CATEGORY	CONDITIONS	APPLICABLE PROCEDURE
Aircraft/Helicopter	Equipment mounted without vibration isolators.	I (par. 6.2.1)
	Equipment mounted with vibration isolators.	I
	Equipment normally using vibration isolators, but tested without vibration isolators.	I (par. 6.2.1)
Air launched vehicle	Equipment mounted without vibration isolators.	II
	Equipment mounted with vibration isolators.	III
	Equipment normally using vibration isolators, but tested without vibration isolators.	IV
Ground launched vehicle	Equipment mounted without vibration isolators.	V
	Equipment mounted with vibration isolators.	VI
	Equipment normally using vibtation isolators, but tested without vibration isolators.	VII
Ground vehicles	General procedure to be used when the vehicle (in which the equipment is to be mounted) or its mileage schedule is not known.	I (par. 6.2.1)
	For more realistic testing when the vehicle is known.	VIII
	Used in addition to procedures I and VIII when the equipment might not always be installed but may be carried in a vehicle.	IX
Shipment by common carrier land or air	Equipment shipped as tied down cargo.	X
	Equipment shipped as loose cargo	XI
Ground equipment, excluding ground vehicles	Generally used for tied down ground equipment	X
	Used in addition to procedure X when ground equipment might be subjected to rough handling.	XI

Table A-IV. Suggested Vibration Test Curves (launched vehicles).

Vehicle Type	Vibration Test Curves		Approx. thrust to weight ratio or thrust in pounds	Equipment location by vehicle section
	Sinusoidal Fig. 3	Random Fig. A-4		
Air launched (flight phase)	S	AK	20/1 or greater	Booster
	R	AJ	5/1 thru 20/1	
	Q	AH	5/1 or less	
	Q	AG	15/1 or greater	All except booster
	P	AF	Less than 15/1	
Ground launched	P or Q	AE,AF, or AG	ALL-	All except booster
	Q or R	AH,AJ, or AK	250,000 lb. or less	By individual booster stage
	R or S	AK,AL, or AM	250,000 - 500,000 lb.	
	T or U	AM,AN, or AP	over 500,000 lb.	

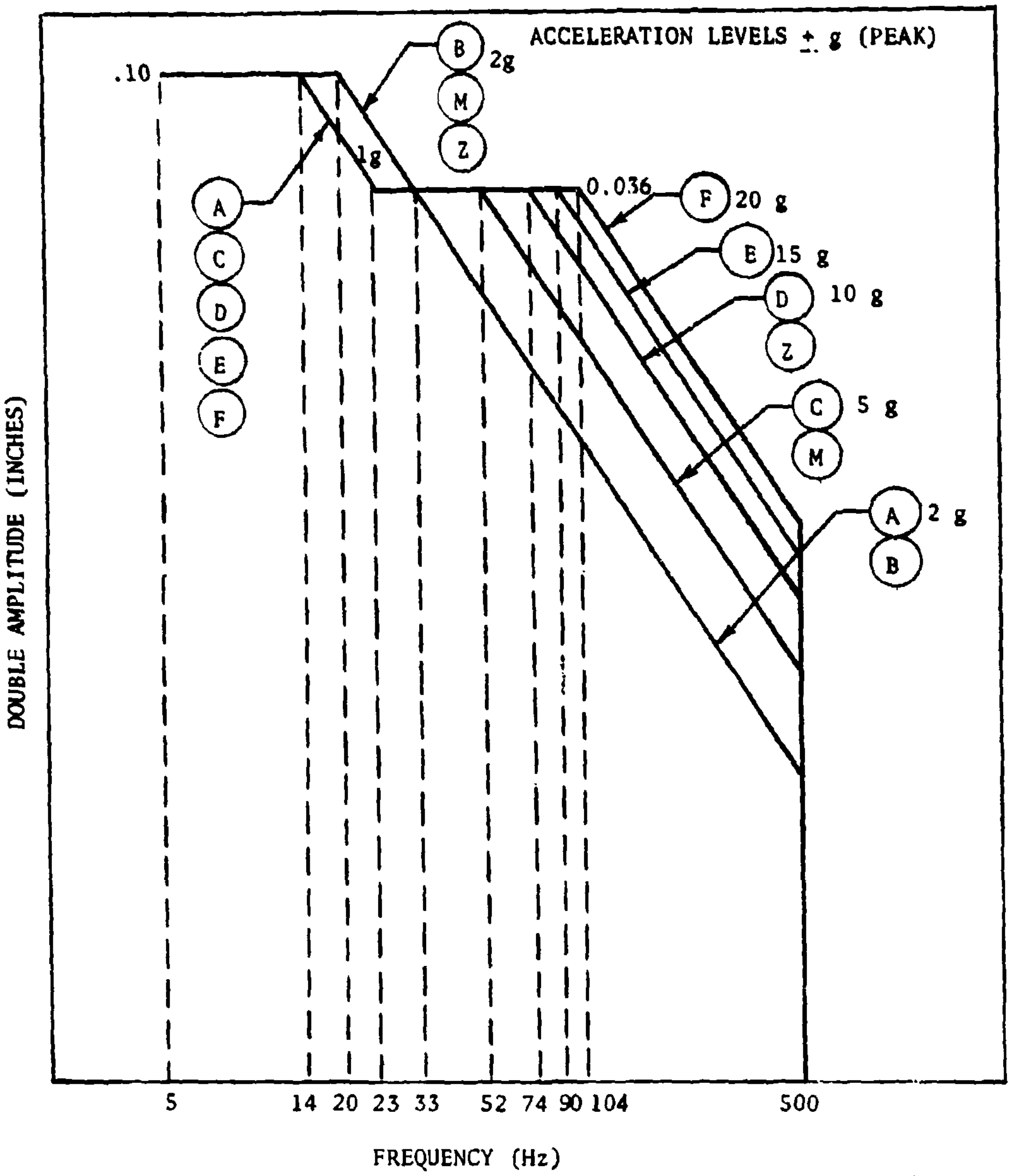


Figure A-1. Vibration Test Curves (sinusoidal) Aircraft and Helicopter, and Air Launched Vehicle (captive phase) Equipment with Maximum Frequency of 500 Hz.

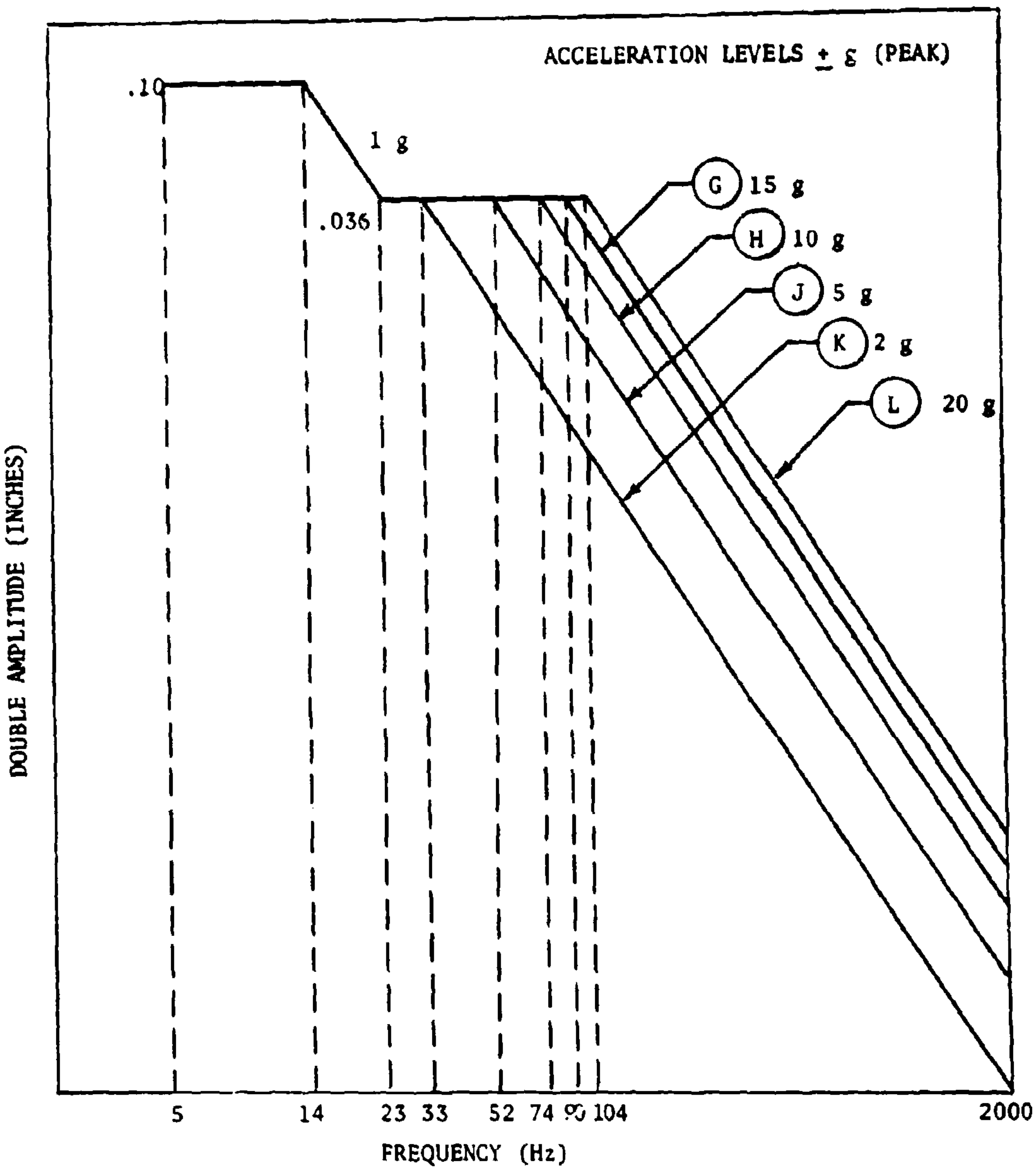


Figure A-2. Vibration Test Curves (sinusoidal) Aircraft and Air Launched Vehicle (captive phase) Equipment with Maximum Frequency of 2000 Hz.

NOTES FOR FIGURES A-1 and A-2

CURVE	AIRCRAFT EQUIPMENT LOCATION
A	Equipment installed on vibration isolated panels and racks when the panel or rack is not available for test and when specified in Table A-I for aircraft application.
B	Equipment installed on vibration isolated panels and racks when the panel or rack is not available for test and when specified in Table A-I for helicopter application.
C	Equipment in forward half of fuselage or equipment in wing areas of aircraft with engines at rear of fuselage.
D	Equipment in rear half of fuselage or equipment in wing areas of aircraft with wing mounted engines or other locations not specifically mentioned for other curves.
E	Equipment located in the engine compartment or pylon.
F	Equipment mounted directly on aircraft engine.
G through L	Same as A and C through F where higher frequencies are anticipated.
M	Equipment designed for helicopter application.
Z	Equipment designed for both helicopter and airplane application.
	AIR LAUNCHED VEHICLE (captive phase)
A,B	Same as for aircraft.
C	Equipment in vehicle attached to wing of aircraft with engine in rear of fuselage.
D	Equipment in vehicle carried in aircraft fuselage or attached to wing in aircraft with wing mounted engines.
H through K	Same as A, C, and D where higher frequencies are anticipated.

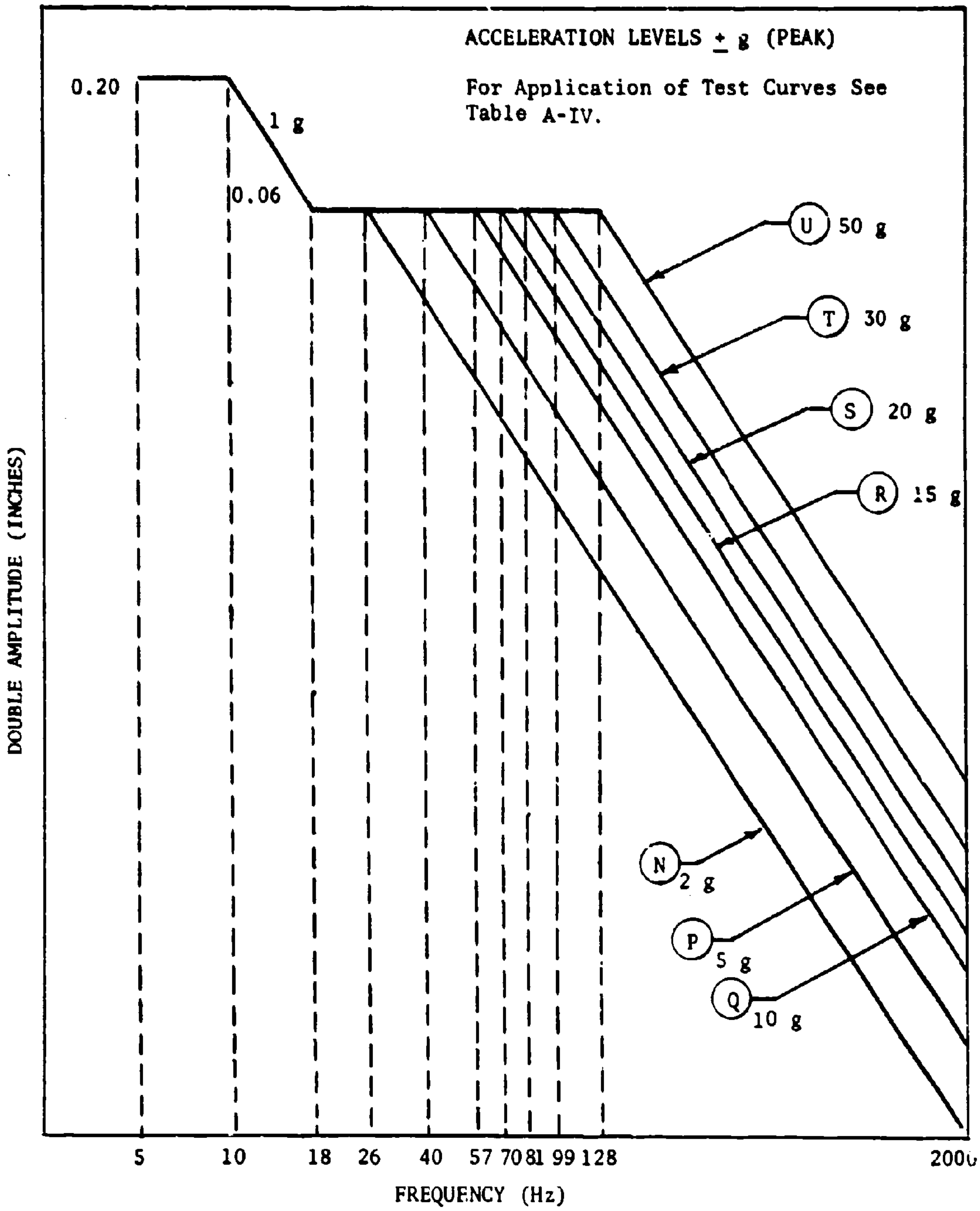
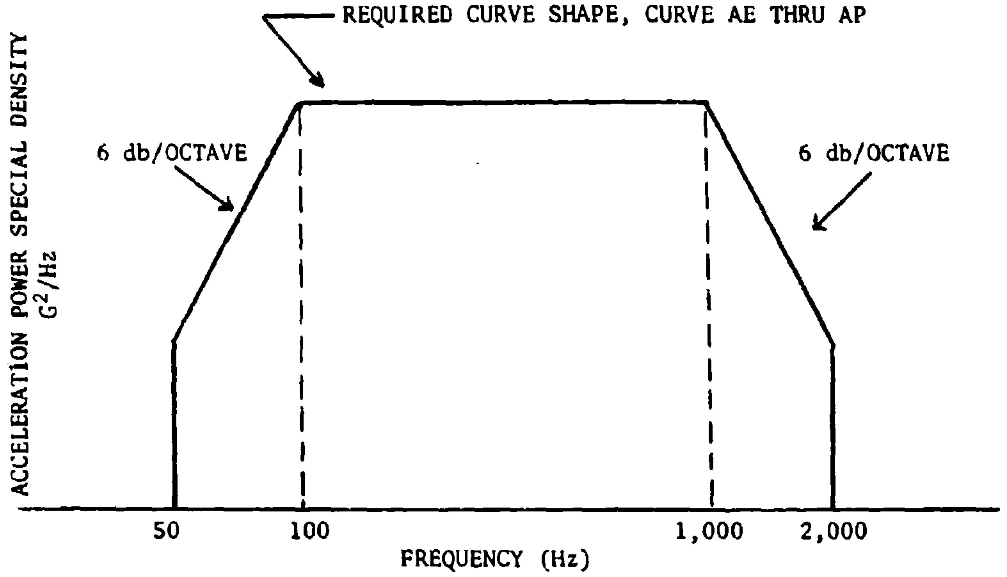


Figure A-3. Vibration Test Curves (sinusoidal), Air Launched Vehicle (flight phase) and Ground Launched Vehicle (flight phase) Equipment.

RANDOM VIBRATION TEST CURVE ENVELOPE



TEST CURVE	ACCELERATION POWER SPECTRAL DENSITY	OVERALL RMS G MINIMUM
AE	0.02	5.3
AF	0.04	7.4
AG	0.06	9.3
AH	0.1	11.9
AJ	0.2	16.9
AK	0.3	20.7
AL	0.4	23.9
AM	0.6	29.3
AN	1.0	37.8
AP	1.5	46.3

NOTE: OVERALL RMS G = $\left(\int_{f_1}^{f_2} W(f)df\right)^{1/2}$ Where f_1 & f_2 are the lower and upper test frequency limits respectfully; & $W(f)$ = acceleration power spectral density, in G^2/Hz units.

Figure A-4. Vibration Test Curves (random) Air Launched Vehicles (flight phase) and Ground Launched Vehicles (flight phase) Equipment.

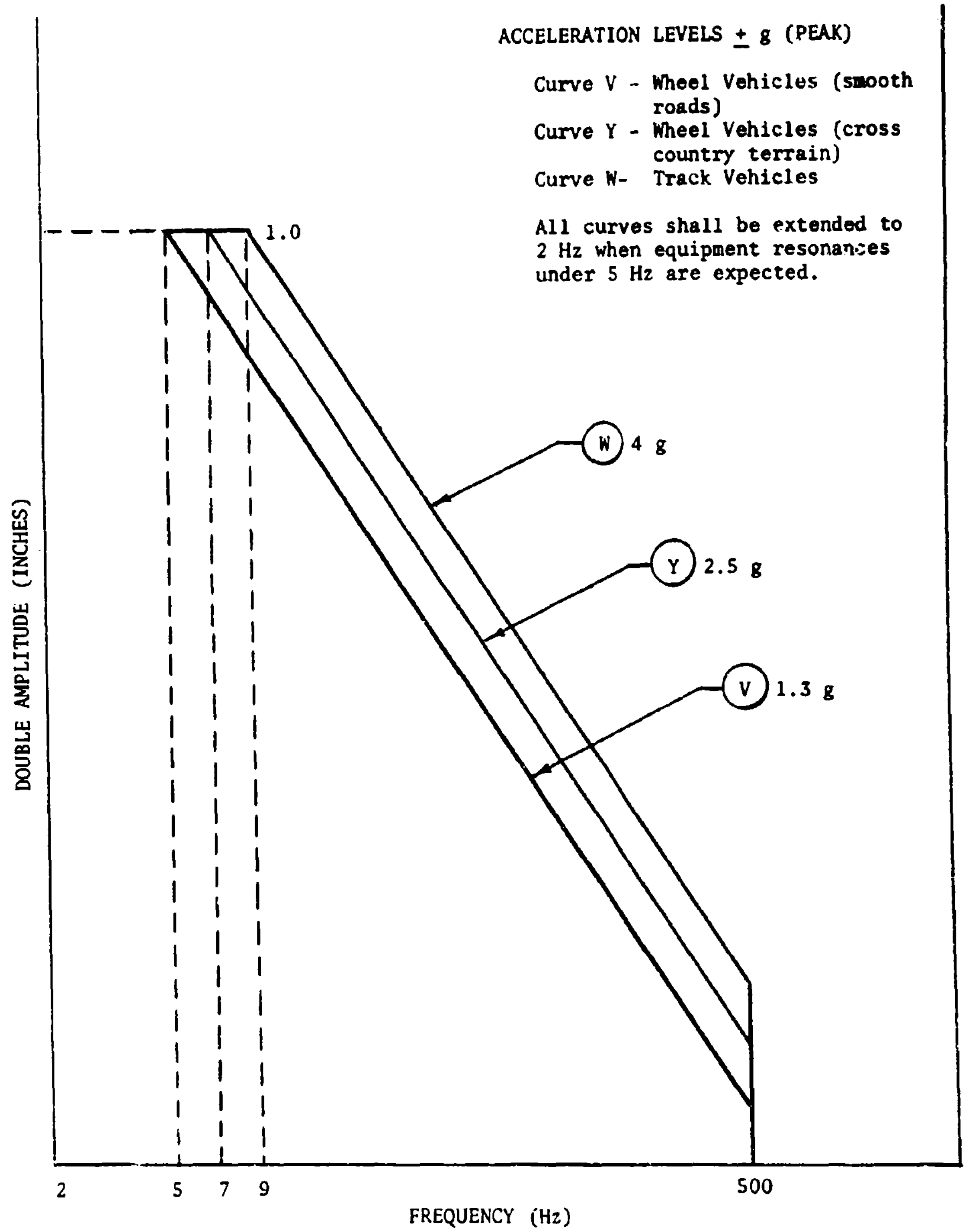


Figure A-5. Vibration Test Curves (sinusoidal) Equipment Installed in Ground Vehicles.

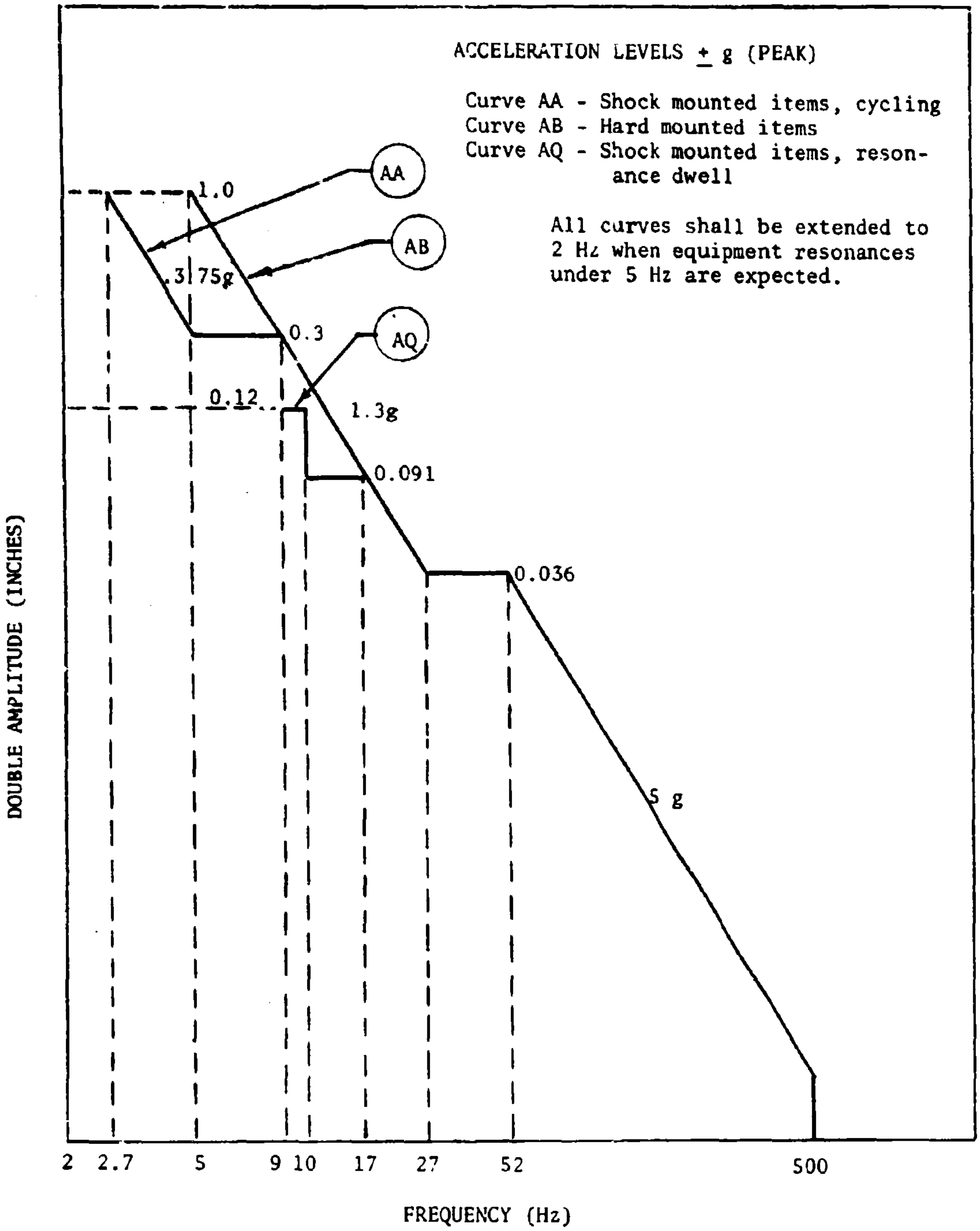


Figure A-6.Vibration Test Curves (sinusoidal) Ground Equipment and Equipment Transported by Common Carrier (land or air) Tied Down.

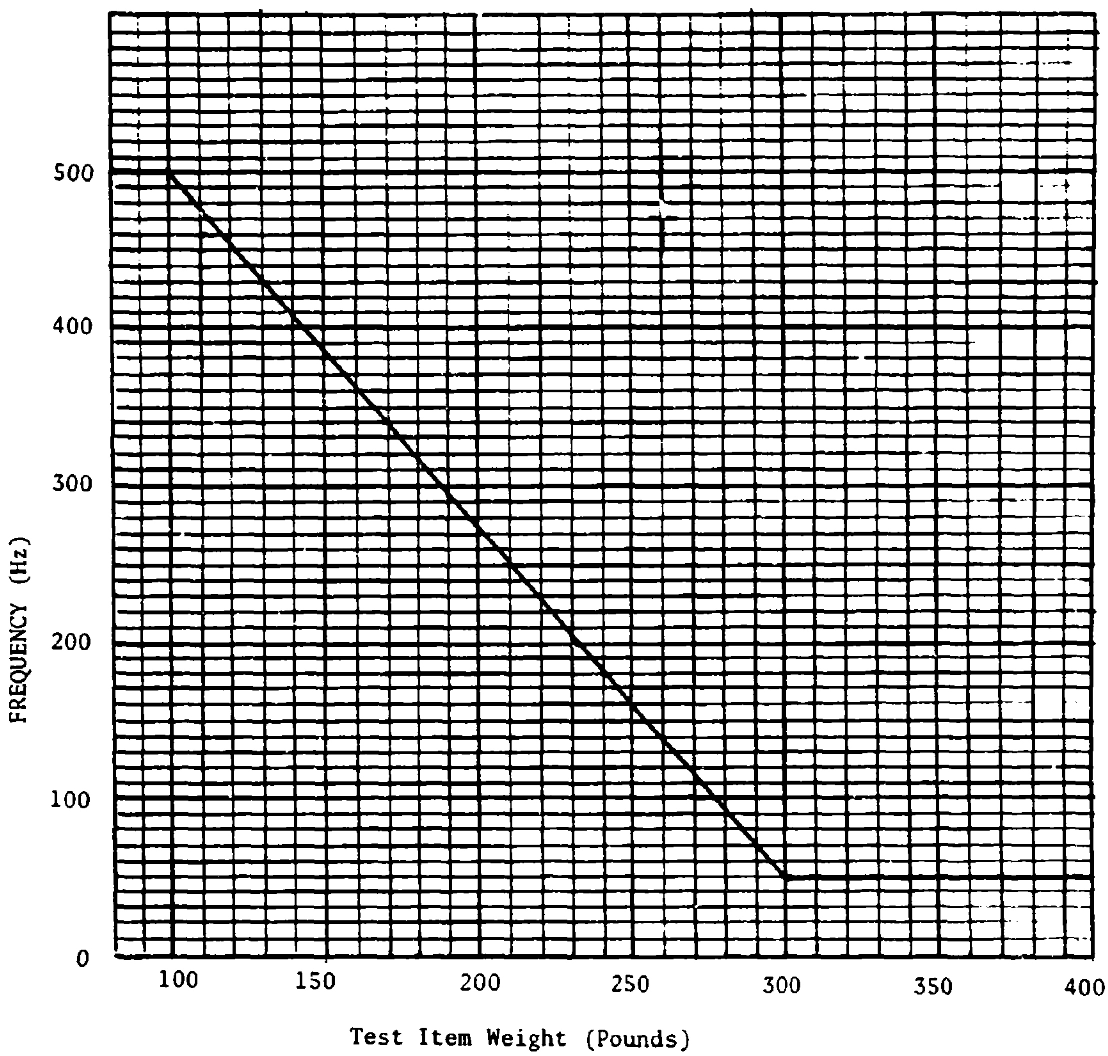


Figure A-7.Cut-off Frequency vs. Weight. Equipment Shipped by Common Carrier, Ground Equipment and Equipment Installed in Ground Vehicles.

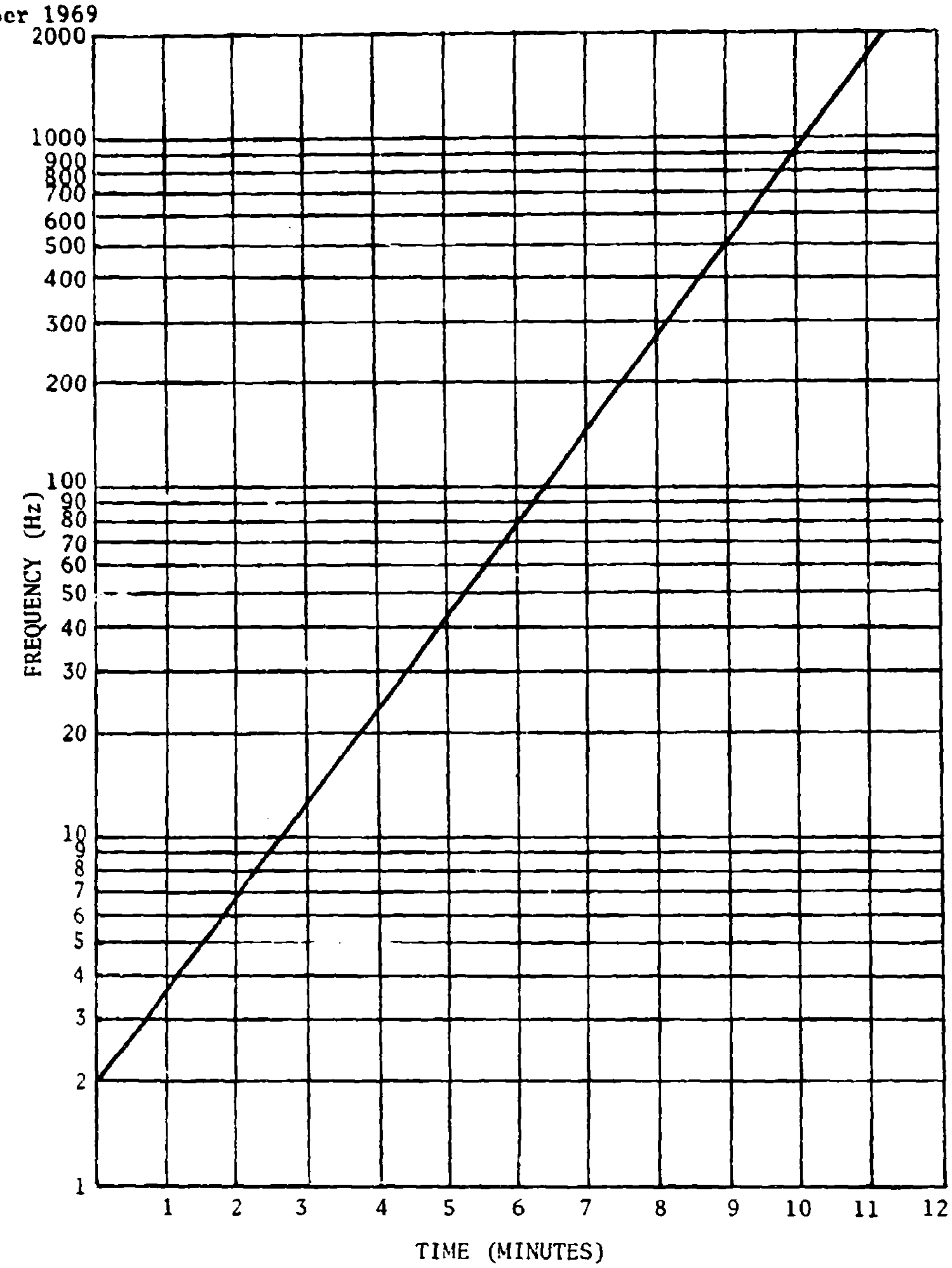


Figure A-8. Logarithmic Cycling Rates: For Cycling Tests Less than 500 Hz Maximum Frequency, the Frequency Range Shall be Cycled Logarithmically from 5 Hz to Maximum in 7.5 Minutes for the Total Cycling Time Specified.

APPENDIX B

VIBRATION MACHINES AND MEASUREMENT SYSTEMS

1. GENERAL

This document describes the capabilities and operation of the vibration machines and vibration measurement systems currently in use at the Environmental Test Facility of the U. S. Army Electronic Proving Ground, Fort Huachuca, Arizona.

2. VIBRATION TESTING SYSTEM

2.1 CAPABILITIES

A block diagram of the vibration testing system is shown in Figure B-1.

a. Type: Air-cooled electrodynamic, driven by a 9 kva electronic power amplifier.
b. Vector Force (sine): 4000 lbs. peak.
c. Frequency Range: 5Hz to 3500 Hz.

NOTE: Rated performance over this frequency range is shown in Figure B-2.

d. Examples of Payload Limitations: 163 lb. at 20g
43 lb. at 50g
3 lb. at 100 g
e. Table Displacement: 0.8 in. at 5Hz (1.25 in. with reduced field).
f. Shaker Table Size: 13/14 in. diameter (12 in., 8 in., and 4 in. mounting-hole circles).
g. Armature Assembly Effective Weight: 37 lb.
h. Free Table Axial Resonant Frequency: 2900 Hz.
i. Sweeping Speed: 132 steps from 0.15 to 15 octaves per minute.
j. Stray Magnetic Field: Less than 15 gauss at 3 inches above any point on the table with full field.
k. Slip Table Weight: 79 lb.
l. Slip Plate Mounting Area: 30 in. x 30 in.

2.2 OPERATION

Actions to be taken in preparing the vibration testing system for testing include but are not necessarily limited to the following manufacturer-recommended checks:

a. Preparation for operation

1) Turn Wall Power On.
2) Turn Amp. Gain Switches down (full CCW) located on master

preamp chassis and on slave preamp chassis.

3) Turn the oscillator gain down (full CCW).
4) Push the "Preamp On" button on the meter panel. The "Preamp" On" light should light, the console fans should start, and the console instruments should come on. After a minute or two time delay, the "Standby" light should light.
5) Push the "Operate" button to apply the plate voltage to the output tubes. The shaker field should come on (if the powerstat is turned up), the shaker blower should start and the "Operate" light should light.

NOTE: Hold the "Operate" button down until the blower pulls in the air switch.

6) After a warmup period, if the shaker field current is not 46 amps., adjust the powerstat to this rated field current.

NOTE: Normally this powerstat setting is not disturbed in turning the system on or off.

7) Following the above steps, the system is ready for operation. To drive the system within rated performance as given in Figure B-2, turn up the "Amp Gain" on the master preamp chassis and operate the oscillator gain and frequency control as required (manual, or automatic sweeping between settable high and low frequency limits with adjustable sweeping rate). Keep the "Amp. Gain" switch on the slave preamp in a low-gain position.

NOTE:

1. Overdriving the system beyond ratings will trip a protective device, thereby putting the system on standby.
2. To put the system on standby operation at any time, push the "Standby" switch. This removes the high voltage from the output tubes, and turns off the shaker field and the shaker blower. However, the instruments and output tube filaments stay on, permitting restartup without a time delay cycle.
3. To resume operation at any time, turn down the "Amp Gain" switch and push the "Operate" button. If the "Amp Gain" switch is not turned down first, the system will not operate.
4) To shut off the system, place the "on-off" switch in the "off" position. Although the system will completely shut off regardless of whether operating manually or automatically, when operating under automatic frequency cycling observe normal shut down procedure for this mode.

CAUTION: The shaker blower rotation should be as indicated by the arrow on the blower. Check the direction of rotation on

initial startup and whenever the system is relocated, or the 3-phase power line is changed.

b. Table accelerometer sensitivity spot check

1) With a rigid mass load (for example a weight of 3 pounds including bolts) centrally attached to the shaker table, locate the optical head of the electro-optical tracking system in a position such that an optical discontinuity on the load lies within the field of view of the optical head lens.

NOTE: If the load does not present the necessary built-in optical discontinuity, affix a strip of white tape with half of it blackened to the load, thereby presenting a sharply-defined color interface perpendicular to the direction of motion.

2) Adjust the operating frequency of the vibration testing system to exactly 20 Hz (on frequency counter) while using a moderate level of amplitude.
3) Adjust the displacement of the table and load to some value within the rated performance of the vibration testing system (for example 0.5 inch peak-to-peak), using the electro-optical tracking system for measurement of displacement.

NOTE: For any displacement (d), the shaker table acceleration may be calculated using,

$$G = \frac{d/2 \times 4 \pi^2 \times f^2}{386} = 20.4\ d \quad (\text{For } f = 20 \text{ Hz})$$

where d = inch (peak-to-peak displacement), and f = Hz (cycles per second).

4) Verify the displacement or acceleration level indicated by the vibration testing system by comparing it with the independently-measured or calculated value, respectively.

c. Rated performance check

With the rigid mass load attached to the table, verify that the vibration system will generate rated performance as indicated in Figure B-2, by varying the frequency throughout the rated frequency range and observing whether rated acceleration or velocity is attained with good acceleration waveform, at selected frequencies.

NOTES: 1. At frequencies below the flat acceleration portion of the curves shown on the system performance plot (Figure B-2), the velocity of the shaker table motion becomes important. The velocity of the driver coil in the high density magnetic field generates a back emf which opposes the voltage

supplied by the Power Amplifier. Hence, in this frequency range table motion becomes limited by velocity rather than acceleration.

2. In those cases where the full rated shaker force is not required or generated at the velocity limit, larger table motions can be obtained by lowering the field coil current. To set the Powerstat knob for optimum field current at a given operating frequency, first place a moderate amplitude on the system with full field (46 amp.) and then reduce the field current until maximum table motion is observed. Holding this field, adjust the amplitude control until desired displacement is obtained.
3. In all cases, avoid over-driving the power amplifier or contacting the stroke limiting snubbers in the shaker. A rough indication of amplifier over-drive is the point of abrupt deterioration of the acceleration waveform.

3. VIBRATION TRANSPORTATION SIMULATOR

3.1 CAPABILITIES

a. Type: L. A. B. Corporation type 1000 SC
b. Table Size: 5 ft. x 5 ft.
c. Load Capacity: Variable (1000 lb. max.)
d. Basic Motions: Circular synchronous, non-synchronous or synchronous 30° out-of-phase, and vertical linear.

3.2 OPERATION

Actions to be taken in preparing the transportation simulator for testing include but are not necessarily limited to the following manufacturer-recommended steps:

a. To prepare for vertical linear motion, proceed as follows:

1) Set the driving pin for synchronous motion and lock both of the vertical-linear triangular rocker plates to the angle brackets on the base frame. To accomplish this, loosen the locking bolts which are positioned in the slots of the angle brackets and then slide them horizontally until they engage the slots in the triangular rocker plates. Slight rocking of the variable speed pulley back and forth may be necessary to exactly align the slots in the rocker plates and angle brackets so that the bolts may be easily slid into position. Tighten the locking bolts firmly so that the rocker plates are securely clamped to the angle brackets.

CAUTION: To prevent damage, do not attempt to start the machine at this point. The table is firmly locked to the base frame and cannot move in any direction.

2) Then, remove the locking bolts from both of the link blocks on the primary shaft so that they become loose link mechanisms similar to those on the secondary shaft. The vertical-linear stabilizer mechanism will not restrain the table from horizontal motion and will allow it to move in the vertical direction.

b. To change from vertical-linear motion back to circular-synchronous, or any other motion, first, reinsert and tighten the fixed link locking bolts on the primary shaft mechanism before removing the locking bolts from the slots on the triangular rocker plates of the vertical-linear stabilizer mechanism.

CAUTION: Unless the above procedures are strictly adhered to, the table frame might be left in an unstable condition. This will occur when both the primary shaft link mechanisms are loose and there is no horizontal restraint by the engagement of the locking bolts in the slots of the triangular rocker plates of the vertical link mechanism. If this condition should accidentally occur, jack up and support the table until the vertical-linear rocker plates are locked or the primary shaft link mechanism bolts are engaged.

4. VIBRATION MEASUREMENT SYSTEM

The current basic vibration measurement system, that is, one accelerometer channel out of a possible six or more, for use in the frequency range 5 to 6000 Hz, is shown in Figure B-3. The switch (or connection) provides for recording either the accelerometer output on a linear time base, or the logarithm of the accelerometer output on a log-frequency X-axis, respectively.

An alternate channel on both the oscillograph and the converter-recorder provide for recording the shaker control signal concurrent with the test item accelerometer output.

For optical measurement of vibration displacement, an electro-optical tracking system, with oscilloscope-camera combination as required, as shown in Figure B-4 is utilized.

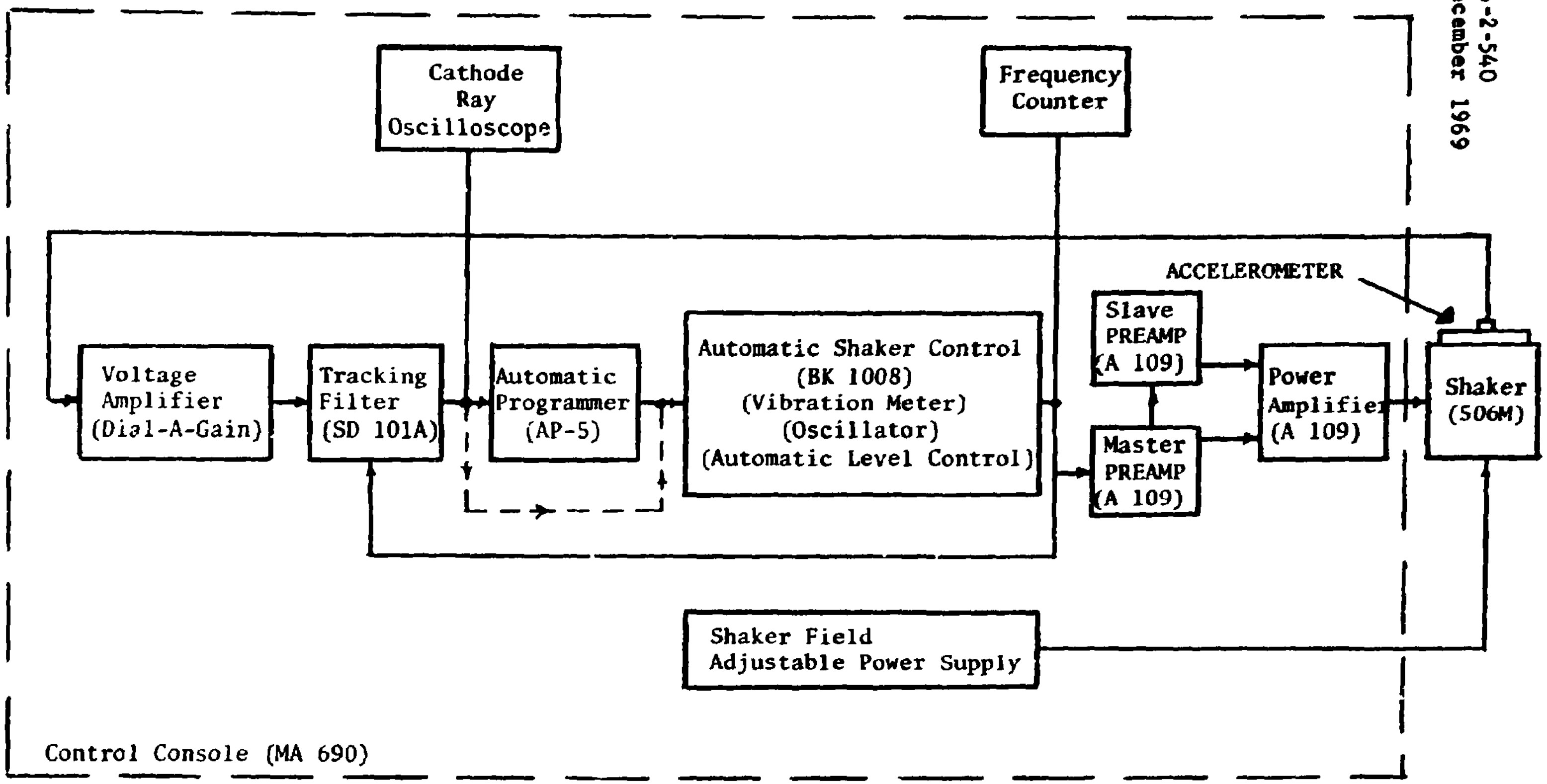


Figure B-1. Block Diagram of Vibration Testing System (690 M-40).

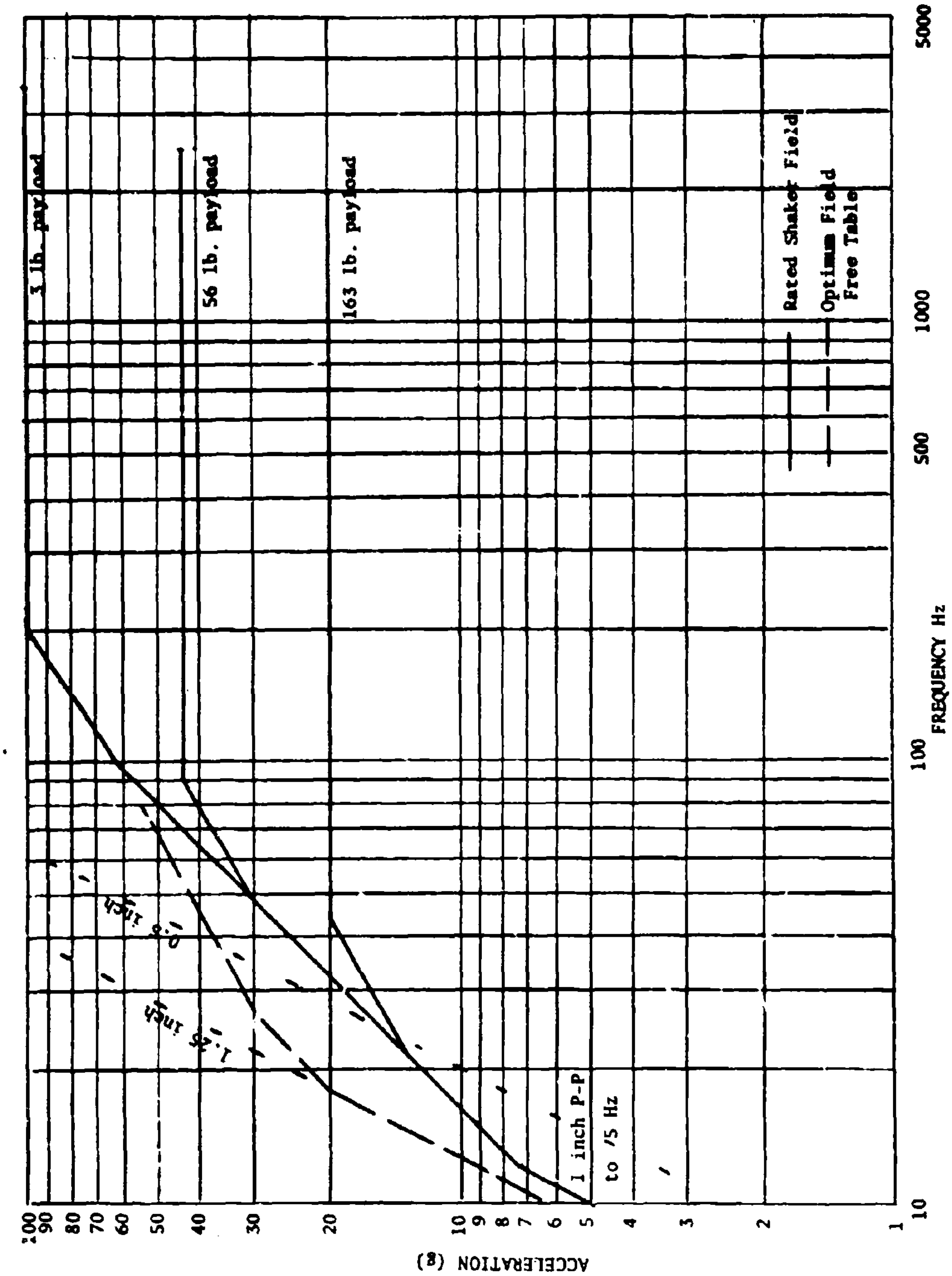
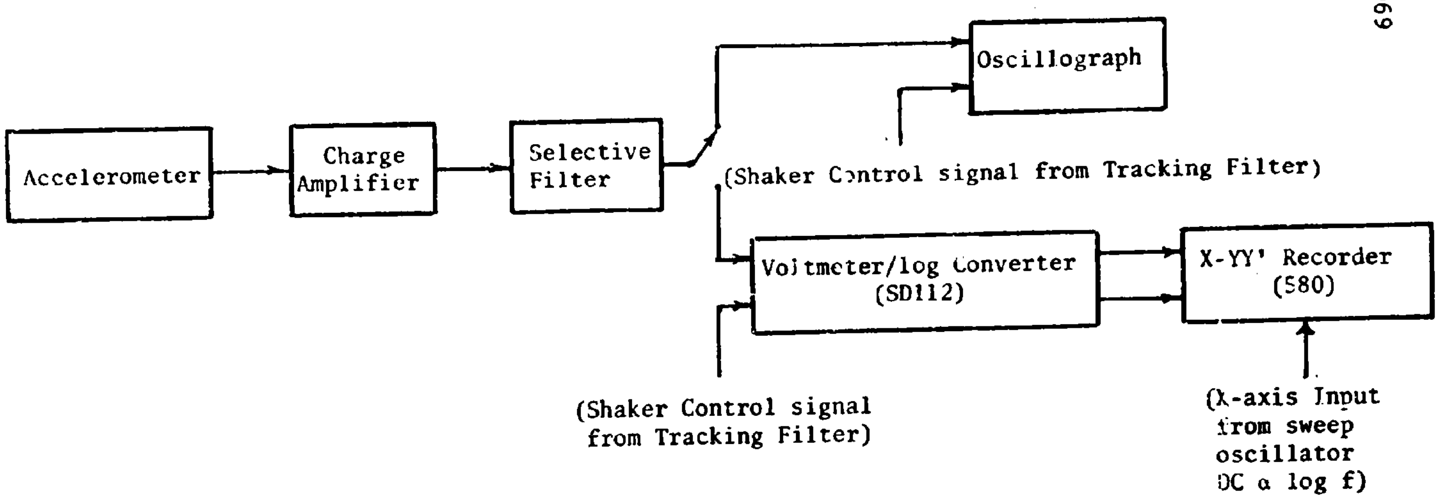


Figure B-2. Rated Performance of Vibration Testing System (690M-40)



NOTE: Input signals denoted by arrows without source blocks are derived from the vibration testing system.

Figure B-3. Block Diagram of Basic Vibration Measurement System.

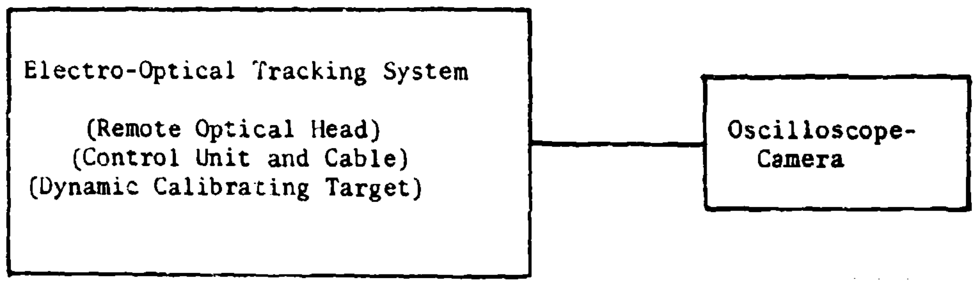


Figure B-4. Block Diagram of Electro-Optical Vibration Measurement System

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APPENDIX C

TEST SEQUENCE

The selection of simulated environments to which to subject a particular test item should be based on a consideration of the natural or induced environments which the equipment will experience during its life cycle. When more than one simulated environment is required to duplicate the effects of a complex environment, a sequence of testing should be specified. Table C-1 provides advisory information on the applicability of the various simulated environments tests and recommended test sequences for various equipment classifications or groups.

NOTE: 1. Test sequence is given in vertical column. A superscript adjacent to the sequence number is explained as follows:

a. ^{1}= Test with limited application.
b. ^{2}= Test recommended for missile in addition to those tests not marked with superscript.
c. ^{3}= Test not generally applicable to airborne or ground launched vehicles.
d. ^{4}= Test not generally applicable to ground launched vehicles.

2. GROUP I

a. A= General Base (sheltered)
b. B= General Base (unsheltered)

} All ground equipment not included in electronics and communications, or aircraft and missile support classes.

c. C= Aircraft and missile support. Equipment used outdoors on airfields and missile launching pads for servicing, maintenance support, checkout, etc. Electronic equipment not included.
d. D= Communications and electronics (sheltered)
e. E= Communications and electronics (unsheltered)

} Communication and electronic equipment of all types and equipment with electric circuits.

3. GROUP II

Equipment installed in airplanes, helicopters, air launched and ground launched vehicles. See MIL-STD-810B for guidance in testing satellites and space vehicles.

a. a = Auxiliary power plants and power plant accessories (Primary power plants excluded).
b. b = Liquid systems. Liquid carrying or hydraulic actuated equipment.
c. c = Gas system. Gas carrying or gas actuated equipment.
d. d = Electrical equipment. All electrical equipment but not electronic.
e. e = Mechanical equipment. Equipment having only mechanical operating parts.
f. f = Autopilots, gyros, and guidance equipment, including accessories, but not electronics.
g. g = Instruments including indicators, electric meters, signal devices, etc., but not electronics.
h. h = Armament. Guns, bombing and rocket equipment, but not electronic.
i. i = Photographic equipment and optical devices.
j. j = Electronic and communications equipment.

Table C-1. Recommended Test Sequence (Read Down)

Environment Test	Applicable MTP	Group I (see notes 1,2)					Group II (see notes 1,3)									
		A	B	C	D	E	a	b	c	d	e	f	g	h	i	j
Altitude	6-2-530	1	1	1	3	3	4	2[1]	2	2	2	3	4	3	2	3
Temp - Alt	6-2-530	-	-	-	-	-	5[4]	4[4]	4[4]	4[4]	5[1,2,3]	4[4]	5[4]	5[4]	4[4]	4[4]
High Temp	6-2-531	2	2	2	2	2	1	1	1	3	1	1	1	1	1	2
Low Temp	6-2-531	4	4	3	1	1	2	3[1]	3	1	4	2	3	2	3	1
Temp Shock	6-2-531	5[1]	5[1]	5[1]	5[1]	5[1]	3[1,2]	5[1,2]	5[1,2]	5[1,2]	3[1,2]	5[1,2]	2	4	5[1,3]	5[1,2]
Sunshine	6-2-532	3[1]	3[1]	4[1]	4[1]	4[1]	-	-	-	-	-	-	6[3]	-	-	-
Rain	6-2-533	8[1]	8	7	11[1]	11	-	7[1]	7[1]	8[1]	7[1,3]	-	-	7[1,3]	-	-
Humidity	6-2-534	9	9	8	12	12	8	8	8	9	8	7	9	8	7[1]	11
Fungus	6-2-535	10	10	9	13	13	9	9[1]	9	10	9[1,3]	8	10	9	8[1,3]	12
Salt Fog	6-2-536	11[1]	11	10	14[1]	14	10[1]	10[1]	10[1]	11[1]	10[1,3]	9[1]	11[1,3]	10[3]	9[1,3]	13[1,3]
Dust	6-2-537	7[1]	7	11	7[1]	7	7	11[3]	11[3]	7	11	10	8	11	10[3]	7
Explosive Atm.	6-2-538	-	-	12	8[1]	8[1]	11[3]	-	-	12[3]	-	11[3]	12[3]	12	11[1,2]	8[1,2]
Immersion	6-2-539	6	6	6	6	6	6	6	6	6	6	6	7	6	6	6
Vibration	6-2-540	13	13	14	10	10	13	13	13	14	13	13	13	14	13	10
Shock	6-2-541	12	12	13	9	9	12	12	12	13	12	12	14	13	12	9

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13. ABSTRACT

This Engineering Test Procedure describes laboratory test methods and techniques for determining the effects of simulated vibration on the performance and physical characteristics of Communications, Surveillance, and Avionic electronic equipment. The evaluation is related to criteria and requirements expressed in applicable Qualitative Materiel Requirements (QMR), Small Development Requirements (SDR), or other appropriate specifications or requirements documentation.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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